What's Happening in Geologic Time
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In this activity, you will work as a group to illustrate the major events that occurred during a specific time in the Earth’s history.

Materials:
- Information cards describing events, flora, and fauna of geologic periods
- Large sheets of paper for drawing
- Marker pens/pencils
- Geologic Time Lines

Activity:
- Divide the class into three groups and assign each group a geologic Era: Paleozoic, Mesozoic, Cenozoic
- Hand out information cards and geologic time lines to each group.
- Have each group identify the geologic time Periods that they will be working with. For example, the Mesozoic Era consists of the Triassic, Jurassic and Cretaceous Periods. Each group should study and discuss the information that relates to their Era and determine what information they feel is most important to present.
- Pass out paper and pens/pencils. Each group will illustrate their geologic Era.
- Each group can decide how they want to represent their geologic Era, but they should include important evolutionary trends, the time span, comments on climate and global conditions, and why their geologic Era is important. Artistry is not as important as information!
- Have each group present their project to the whole class. Discuss important events that occurred in each geologic Era. Talk about how events that occurred in previous geologic times affected later events and how they affected the world as we know it today.
Precambrian
4.6 billion – 543 million years ago

The Precambrian was a time in Earth history before the evolution of hard-bodied and complex organisms. For most of this Period, the only life was single celled organisms. During the Late Precambrian, simple, soft-bodied marine life evolved, a very small fraction of which was preserved. There was no life on land.

Events in the Precambrian:

• 4.6 – 3.8 billion years ago - molten material that resulted from the accumulation of small planetesimals started to cook and solidified into rocks, most of which were not preserved.

• 3.8 billion years ago - the oldest known terrestrial rocks were formed and are now found in present day Australia.

• 3.5 billion years ago – evolution of cyanobacteria, also called blue-green algae. These cellular organisms lived in large mounds in the ocean, called stromatolites. Stromatolites dominated the world for the next 2.5 billion years!

The most important evolutionary product of the Precambrian was the cell, from which all further life developed.
In the Late Precambrian most of the landmass of the Earth was locked up in a single continent called Rodinia. At this time, marine organisms began to colonize the seafloor around the margins of this ancient continent. Precambrian fauna were all soft-bodied and exclusively marine. Below are illustrations of some of the organisms that existed during the latest Precambrian.

- 640 – 534 million years ago The end of the Precambrian Period is a time known as the Vendian, when a group of large soft-bodied fossils collectively known as the Ediacara fauna first appeared.

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Cambrian Period
540 – 488 million years ago

This Period is considered that time when life on Earth diversified and is often referred to as the “Cambrian Explosion.” It was during this time that the first animals with exoskeletons evolved, most notably Trilobites, Brachiopods, and Molluscs as well as the Echinoderms and Sponges.

Events in the Cambrian

• Life is completely confined to the oceans

• Predators became prevalent in the Cambrian, influencing the evolutionary pathways of many species.

Trilobites – marine arthropods

The inarticulate brachiopod Lingula that evolved in the Cambrian is still around today!

Hallucigenia, an inch long spiny worm-type creature. Which is the head end?
At the beginning of the Cambrian, only small sponges and molluscs were present, but by about the middle of the Period, diversification of the shelly fauna occurred.

Below: In the foreground the arthropod *Anomalocaris* has captured a trilobite. On the sea floor from left to center are a solitary specimen of *Wiwaxia* and three specimens of *Hallucigenia*. From *The Crucible of Creation* by Prof. Simon Conway Morris.
Ordovician Period
488 - 443 million years ago

The Ordovician was an age of evolutionary experimentation, in which new organisms evolved to replace those that died out at the end of the Cambrian. It was also one of the largest adaptive radiations in the Earth's history. The number of families of known marine invertebrates increased from about 200 at the end of the Cambrian to around 500 in the early Ordovician.

Events in the Ordovician

• There was a dramatic increase of the articulated brachiopods, corals, bryozoans and other filter-feeding organisms.
• First appearance of the corals, including both rugose and tabulate forms, bivalve molluscs.
• First appearance of land organisms in the form of plants and small arthropods.
• By the end of the Ordovician Period, primitive jawless fish called Ostracoderms appeared.

Ostracoderm – a jawless, armored fish. One of the first true vertebrates.

Graptolites are common fossils in Ordovician rocks, but for a long time no one was sure what kind of animals they were. Most graptolites are thought to have been planktonic, floating or slowly sinking through the water.

Bryozoan

Graptolite
During the Late Ordovician, massive glaciers formed, causing shallow seas to drain and sea levels to drop. This may have caused the mass extinctions that characterize the end of the Ordovician, in which 60% of all marine invertebrate genera went extinct.

In Brachiopods, each shell valve is symmetrical about the midline, but the two shell valves are often unequal in size. In articulate brachiopods, the hinge axis is lined with a set of interlocking teeth and sockets, while inarticulate brachiopods, open and close their shells with muscles.

A typical Ordovician marine community might have consisted of graptolites, trilobites, brachiopods, red and green algae, cephalopods, corals, crinoids, and gastropods (illustrated below).

Articulate brachiopods

A cephalopod captures a trilobite. From Earth History Resources
Silurian Period
443 - 417 million years ago

Following the Ordovician extinction event there was a rapid recovery of invertebrate faunas during the Silurian. A substantial rise in sea level occurred during this period, leading to the development of large coral reefs. The Trilobites, having reached their peak in the Cambrian and Ordovician, declined dramatically during the Silurian.

Events in the Silurian
• Oldest fossil evidence of vascular land plants, *Cooksonia*.
• Oldest fossil evidence of land animals, *Pneumodesmus*, a small millipede.
• First appearance of jawed fish and freshwater fish.

*Cooksonia*, a collection of branching-stemmed plants which produced sporangia at their tips.

*Platyceras*, a marine gastropod.

*Paleophonus nuncius*, a blind aquatic scorpion - length about 5 cm.
Placoderms first appeared in the Early Silurian. Placoderms (=plate skin) are armored by their extensive dermal skeleton.

Marine life in the Silurian: abundant corals, bivalves (molluscs), trilobites, and nautilus-like predators.

Bivalves (molluscs) were common in the Silurian and are still around today. Bivalves have a shell made of two halves, which are also called valves. Bivalves feed on tiny bits of food found in the water or sediment. Some bivalves burrow into the sediment and others live on the sediment surface or are attached to hard objects such as rock or coral.
Devonian Period
417 to 354 million years ago

The Devonian was a time of rapid diversification of fish in the sea and the total colonization of land by plants.

Events in the Devonian:
• Ferns, horsetails and seed plants appeared at the end of the Devonian, producing the first trees and the first forests.
• The first tetrapods (4-footed animals) appeared on land
• The first arachnids appeared

Archaeopteris was essentially the first modern tree with measurements of in excess of 1 m at the trunk and estimated heights of up to 30 m. This was the dominant land plant until the end of the Devonian, at which time it became extinct.

Lungfishes are highly specialized lobe-fins. They exhibit a set of features that helped produce a powerful bite. These include a heavily ossified braincase, the fusion of the palate to the braincase, strengthened gill arches, and specialized tooth plates adapted to either crush or shred food.
During the late Devonian the tetrapods evolved. These were the first vertebrates to truly walk the land; earlier vertebrates were all confined to aquatic habitats. Tetrapods are a name that we have given to anything with four feet (tetra=four, pod=feet).

Acanthostega, one of the most primitive tetrapods

On land, the arachnids evolved during the Devonian. Above is a reconstruction of Palaeocharinus rhyniensis showing the separate lateral (l) and median (m) eye tubercles.

Cladoselache, an early shark

Brachiopods, tabulate and rugose corals, crinoids and other echinoderms flourished during the Devonian.

The first sharks evolved during this period.
Carboniferous Period
354 to 290 million years ago

This period has been separated into the Mississippian (Lower Carboniferous) and the Pennsylvanian (Upper Carboniferous) in the United States. This system was adopted to distinguish the coal-bearing layers of the Pennsylvanian from the mostly limestone Mississippian rocks.

Events in the Carboniferous:

• The evolution of the amniotic egg was very important for all future terrestrial life. These eggs allow modern birds, mammals, and reptiles to reproduce on land rather than in water, by preventing the desiccation of the embryo inside the egg.

• Trilobites were much reduced in numbers, and confined to a single superfamily, the Proetoidea.

• Diapsids (marine reptiles, lizards, and snakes) first appeared during the Carboniferous

• The last of the graptolites died out.

The moist tropical climate produced a lush plant growth, which eventually became great coal deposits (hence the name Carboniferous - "coal bearing"). These plants were abundant and big, up to 30 meters tall, but were tied closely to water – river banks, estuaries and coastlines.
During the Carboniferous, plants continued to diversify and multiply, sucking carbon dioxide from the atmosphere and pumping enough O₂ into the atmosphere to send levels to their highest in geologic history! The oxygen rich atmosphere may have contributed to the evolution of truly gigantic life forms during the Carboniferous.

arthropleurids were a group of small to huge (2 meters) arthropods that lived during the Carboniferous

Meganeura monyi resembled a present-day dragonfly. With a wingspan of more than 75 cm (2 feet) wide, it was the largest known flying insect species to ever appear on earth

During the Carboniferous, a new group of creatures, the cotylosaurs, evolved and are considered the first true reptiles. Cotylosaurs were distinguished by their small size, agile limbs and the amniote egg. With its large shell and protective membranes, the amniote egg gave reptile the freedom to lay their eggs on land.
Permian Period
290 to 248 million years ago

During the Permian, reptiles began to increase in variety on land along two lines: Pelycosaurs, which have long bodies with short legs and large fins, and Therapsids, which carried their bodies off the ground and showed changes in jaw structure with teeth (canines, incisors, and molars) that later appeared in mammals.

Events in the Permian:

• Gymnosperms, plants with their offspring enclosed within seeds, first appear. These include Ginkgos and conifers.

Ginkgo biloba – a gymnosperm that first appeared during the Permian.

A Permian reef showing an abundance of sponges, rugose corals and brachiopods, a gastropod (left), a spiny-shelled nautilid Cooperoceras (right foreground) and a smooth shelled ammonoid (center background).
At the end of the Permian the largest mass extinction occurred in the history of life on Earth. This event affected many groups but especially marine organisms; it is estimated that 90-95% of marine species became extinct at the end of the Permian. This included all trilobites, eurypterids, blastoids, and rugose coral, and about 75% of the existing amphibian and 80% of the reptile families.

The bear-sized gorgonopsid (a therapsid) assaulting the ox-sized armoured pareiasaur herbivore Scutosaurus karpinski (an anapsid) in a late Permian illustration.

During the early Permian, Dimetrodon (top) and Eryops (bottom) dominated the semiaquatic and lowland floodplains.
Triassic Period
248 to 206 million years ago

At the end of the Permian, trilobites, bryozoans, blastoids and rugose corals went extinct. However, other marine organisms including bivalves, ammonoids and brachiopods all recovered and went on to dominate the Triassic oceans.

- Dinosaurs evolved from tetrapods
- Seed-bearing gymnosperms gradually replaced the spore-bearing plants.

During the Triassic period, the climate was mild to hot. Conifers, palm-like cycads and ferns grew in moist areas.

Coelophysis, one of the earliest known dinosaurs, lived about 225 to 220 million years ago. It was a small slenderly built meat-eater, up to 3 meters in length, with sharp claws and teeth.

Postosuchus - the biggest and most active carnivore of the Triassic
Scleractinian corals first appeared in the Middle Triassic and replaced tabulate and rugose corals that went extinct at the end of the Permian. Modern brain corals are scleractinian corals.

*Triadobatrachus massinoti*, a primitive frog-like amphibian from the Lower Triassic

By the end of the Triassic, salamanders, frogs and turtles had evolved, as did the earliest mammals.

*Thrinaxodon liorhinus*, a mammal-like reptile from the early Triassic

•The late Triassic ichthyosaur *Shonisaurus popularis*, the Nevada State fossil, was about 50 feet long and may have weighed 40 tons. It preyed on the fish and ammonites that were abundant in the oceans of that time.
Jurassic Period
206 to 146 million years ago

The Jurassic period saw warm tropical greenhouse conditions, world-wide, shallow continental seas, new and diverse flora and fauna, and the dominance of the dinosaurs and the marine reptiles.

Events in the Jurassic
- The first pterosaurs and birds evolved
- Dinosaurs diversified, grew larger
- Cycads and conifers were abundant
- Several new planktonic organisms evolved: diatoms, dinoflagellates, foraminifera and ostracodes.

Archaeopteryx (meaning ‘ancient wing’) is one of the most famous fossil finds of all time. Archaeopteryx is thought to have been the first known bird, evolving in the Late Jurassic. It was larger than a crow and had sharp teeth, a long bony tail and three clawed fingers. Although Archaeopteryx could probably fly a few feet, it was not capable of flight like a true bird.

Ammonites were chambered mollusks related to modern nautilids. Although they evolved in the Permian, they diversified rapidly and became very abundant in the Jurassic and dominated invertebrate sea life. Some fossil specimens were as wide as 2 m (6.5 feet).
Although the dinosaurs and most of the plant and animal life of the Jurassic became extinct, a few cycads survived, virtually unchanged, and can still be found today in remote regions of the world. They are often referred to as "living fossils."

* Cycas bellefonti* growing on limestone cliffs above surrounding forest in the Cat Ba Islands, Vietnam.

Dinoflagellates (above) and Diatoms (below) are two of the planktonic organisms that originated in the Jurassic.

The long-necked Apatosaurus (center) browsed on tall conifer trees. Allosaurus (foreground) was a large predator that grew to lengths of 12 m (40 ft) and heights of 4.5 m (15 ft). Stegosaurus (background) fed on ground vegetation such as low-lying ferns and cycads.
Cretaceous Period
146 to 65 million years ago

During the Cretaceous, all polar ice that formed during the Late Jurassic melted and temperatures increased dramatically, as much as 20ºC higher than present temperatures. Higher temperatures sped up evolutionary processes, so the diversity of plants and animals during this time was extreme.

Events in the Cretaceous:
• First fossils of many insect groups
• First modern mammal and bird groups
• First flowering plants
• A major extinction event occurred at the end of the Cretaceous that totally wiped out the Ammonoids, Mosasaurs and Plesiosaurs in the oceans and the Dinosaurs on land.

**Flowering plants, not just pretty to look at.**

Nearly all of our food comes from flowering plants; grains, beans, nuts, fruits, vegetables, herbs and spices almost all come from plants with flowers, as do tea, coffee, chocolate, wine, beer, tequila, and cola. Much of our clothing comes from them as well; cotton, linen, hemp, rope and burlap are made from the fibers of flowering plants.

This is a reconstruction of some Late Cretaceous vegetation. The large white flowers, the brownish spiky fruit stalks and associated cleft leaves are all extinct relatives of the magnolia.
A meteor impact may have led to dinosaur extinction?

Rocks deposited during the Cretaceous Period and Paleogene Period are separated by a thin clay layer containing a high concentration of iridium, an element that is much more common in meteorites than in Earth's rocks. Consequently, a theory was proposed by Dr. Luis and Dr. Walter Alvarez that an impacting asteroid or comet hit the Earth, generating the iridium anomaly, and causing the mass extinction event that killed off the dinosaur and other animal groups.

Aphids, grasshoppers, gall wasps, termites, and ants appear in the Cretaceous, but maybe the most important insect to evolve was the eusocial bee, which was integral to the ecology and evolution of flowering plants. *Hymenoptera* (ancient bee), *Yixian Formation*, Liaoning Province, China

A marine scene from the Cretaceous showing a Mosasaur surrounded by ammonites with Pterosaurs flying above. Rays and a Tarponlike fish (*Xiphactinus*) are at the right.
Paleogene Period
Tertiary Sub-Era
65 to 23.8 million years ago

During the Paleogene, mammalian life diversified into an amazing array of species. The reptiles that had dominated the Mesozoic Era lost ground to the mammals of the Cenozoic.

The Paleogene Period can be further divided into the following epochs:

- **Paleocene**: 65 to 54.8 Ma
- **Eocene**: 54.8 to 33.7 Ma
- **Oligocene**: 33.7 to 23.8 Ma

Monkeys, apes and humans are the living descendants of the first anthropoids, which evolved in the Eocene. The first marine mammals, whales and sea cows, also appeared in the Eocene.

This scene is from the Early Paleocene of Wyoming. The vegetation included sequoia trees, with a dense undergrowth of shrubs such as tea and laurel, with the addition of ferns and horsetails. On the ground is *Chriacus*, a raccoon-like omnivore. Facing *Chriacus* on the tree is *Ptilodus*, a surviving member of the multituberculates, primitive mammals often termed the "rodents of the Mesozoic." Higher up in the tree is *Peradectes* (the name means "persisting biter"), an early opossum-like marsupial. Marsupials became extinct in North America by the Oligocene, and did not reappear until true opossums invaded from South America in the Pleistocene.
Around the middle of the Eocene, Earth underwent a dramatic climate change. During that time of global cooling, dense forests were replaced with open forests and grasslands and the polar icecaps began their formation.

*Sespia californica* was a small herbivore, about the size of a domestic cat, with large eyes very high on the skull. A member of a group called oreodonts, these animals were distantly related to living pigs and camels and were alive in the Oligocene.

*Indricotherium* was the largest known land mammal of any time. It resided in Asia during the Oligocene.

Early Paleocene *Purgatorius*, one of the earliest known primate-like mammals.

*Dugong*, a modern relative of the Eocene sea cow.
Neogene Period
Tertiary Sub-Era
23.8 to 1.81 million years ago

The Neogene Period can be further divided into the following epochs:

Miocene 23.8 to 5.32 Ma
Pliocene 5.32 to 1.81 Ma

Events in the Neogene:
• Two major ecosystems first appeared at this time: kelp forests and grasslands
• By the end of the Miocene, 95% of modern seed plant families existed
• The Panamanian land-bridge between North and South America appeared during the Pliocene, allowing migrations of plants and animals into new habitats
• The first bipedal ancestors of humans evolved during the Pliocene

A paleosaber (*Barbourofelis*) ambushes a three-toed *Hipparion*, relative of the modern zebra. Illustration by Carl Buell
In the early Miocene, ape species evolved and diversified in Africa, and by about 16 million years ago, apes spread to Eurasia and began to diversify there as well. During the Miocene epoch, as many as 100 species of apes existed.

*Kelp and grass first appeared during the Miocene, feeding new marine and terrestrial species.*

Pierolapithecus catalaunicus, evolved approximately 13 million years ago and could be a human ancestor.

Homo ergaster – 1.9 million years old and an ancestor to Homo erectus

A number of modern-day families of both toothed and baleen whales evolved by the late Miocene.

The mastodon, a member of the elephant family, was common during the Pliocene.
Quaternary Period
1.81 million years ago to the present

*The Quaternary is marked by glacial advances and retreats and includes periods that were warmer than the present.*

The Quaternary Period can be further divided into the following epochs:

- **Pleistocene** 1.81 to 0.01 Ma
- **Holocene** 10,000 years to present

The Pleistocene saw the evolution and expansion of our own species, *Homo sapiens*.

A scene from the Pleistocene: short-faced bear, *Smilodon* (saber tooth), turkey, fox, mastodons, *Bison antiquas*
At the end of the Pleistocene, about 11,000 years ago, a variety of animals went extinct across North America. These were mostly mammals larger than 100 pounds and included the saber-toothed cats, mammoths, mastodons, the short-faced skunk, the giant beaver and the ground sloth. Some animals that went extinct in North America survived elsewhere, for example, horses, camels and tapirs. Before this extinction, the diversity of large mammals in North America was similar to that of modern Africa. As a result of the extinction, relatively few large mammals are now indigenous to North America.

Welcome to the modern age! *Homo sapiens* have been around for at least the past 120,000 years.